US005871807A

United States Patent [19]

Stansbury

[11] **Patent Number: 5,871,807**

[45] **Date of Patent: Feb. 16, 1999**

[54] **MULTIPLE LEVEL PRINTING IN A SINGLE PASS**

[75] Inventor: **Darryl Stansbury**, Boise, Id.

[73] Assignee: **Micron Display Technology, Inc.**, Boise, Id.

[21] Appl. No.: **514,778**

[22] Filed: **Aug. 14, 1995**

[51] **Int. Cl.**[6] **B05D 5/12**

[52] **U.S. Cl.** **427/64**; 427/64; 427/164; 427/165; 427/229; 427/68; 427/282; 427/389.7; 427/407.2; 427/419.1

[58] **Field of Search** 427/282, 64, 68, 427/229, 287, 164, 407.2, 165, 389.7, 419.1

[56] **References Cited**

U.S. PATENT DOCUMENTS

4,196,227	4/1980	Dubois et al.	427/64
4,775,549	10/1988	Ota et al.	427/66
5,686,135	11/1997	Langevin et al.	427/96
5,687,055	11/1997	Miki	427/79
5,699,733	12/1997	Chang et al.	427/282

OTHER PUBLICATIONS

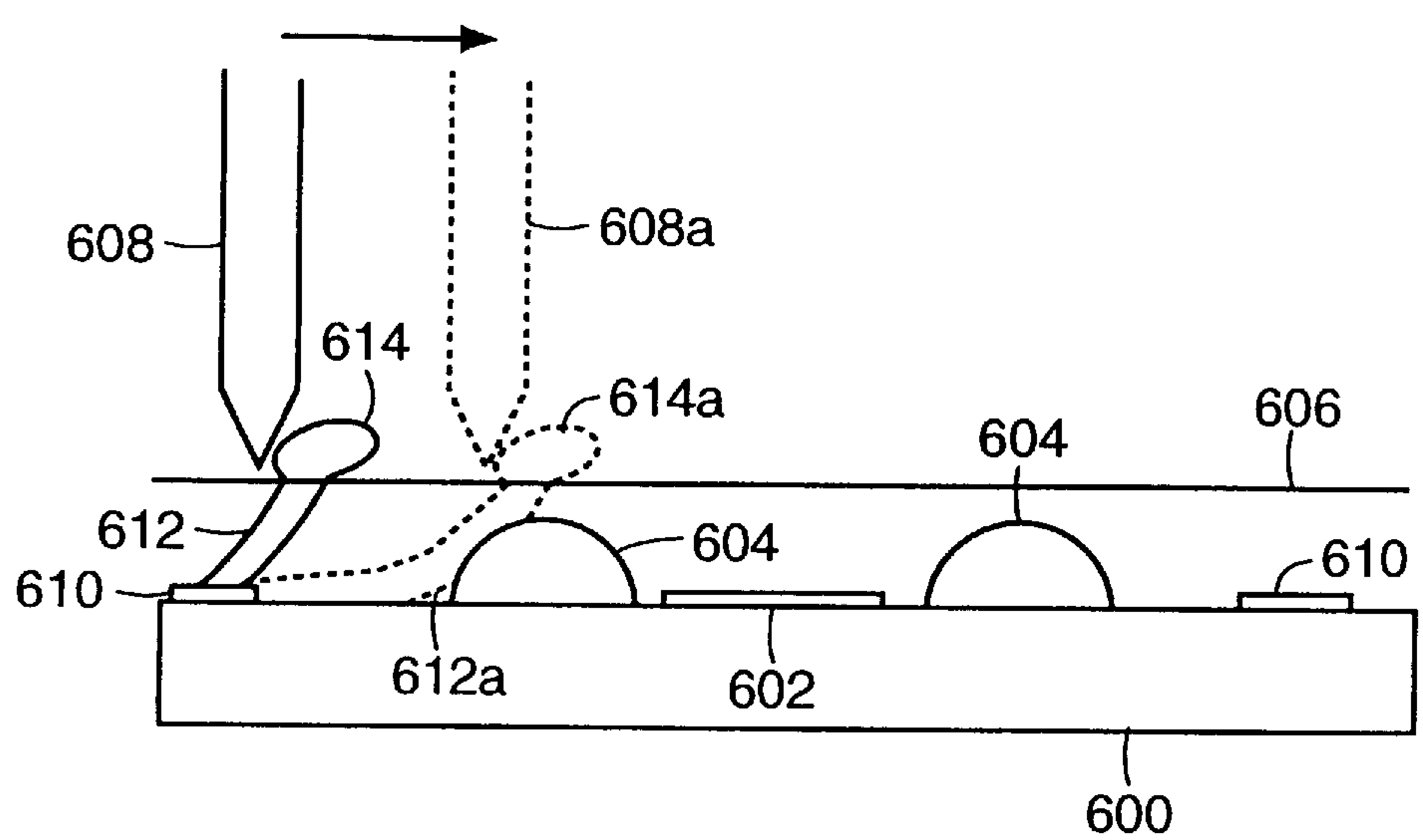
Hieh et al, *Silk Screen Process Production*, 3ed., Blandford Press Limited, London, 1950. pp. 35 and 36, 1950.

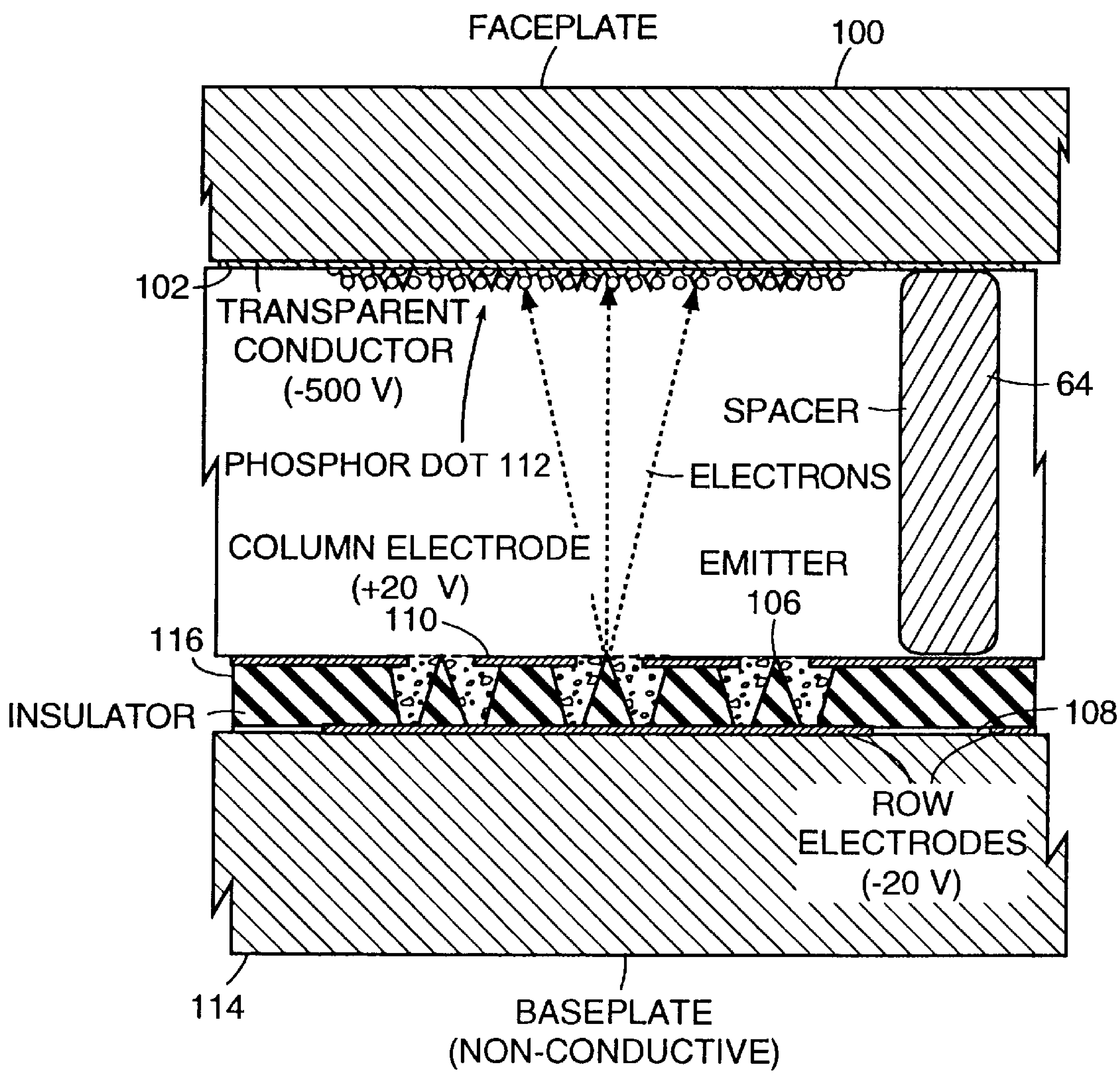
Primary Examiner—Janyce Bell
Attorney, Agent, or Firm—Hale and Dorr LLP

[57] **ABSTRACT**

A process is provided for forming a conductive line between a conductor and a spacer formed on a substrate of a field emission display. In one embodiment, the process performs the steps of disposing a screen between the substrate and a distributing member, the screen having an opening which permits the extrusion a conductive material, and moving the distributing member relative to the screen to extrude the conductive material through the opening and form a conductive line connecting the conductor and the spacer, wherein the snap off distance is varied according as the distributing member moves along the substrate.

23 Claims, 6 Drawing Sheets





FIELD EMISSION DISPLAY
CROSS SECTION

FIG. 1

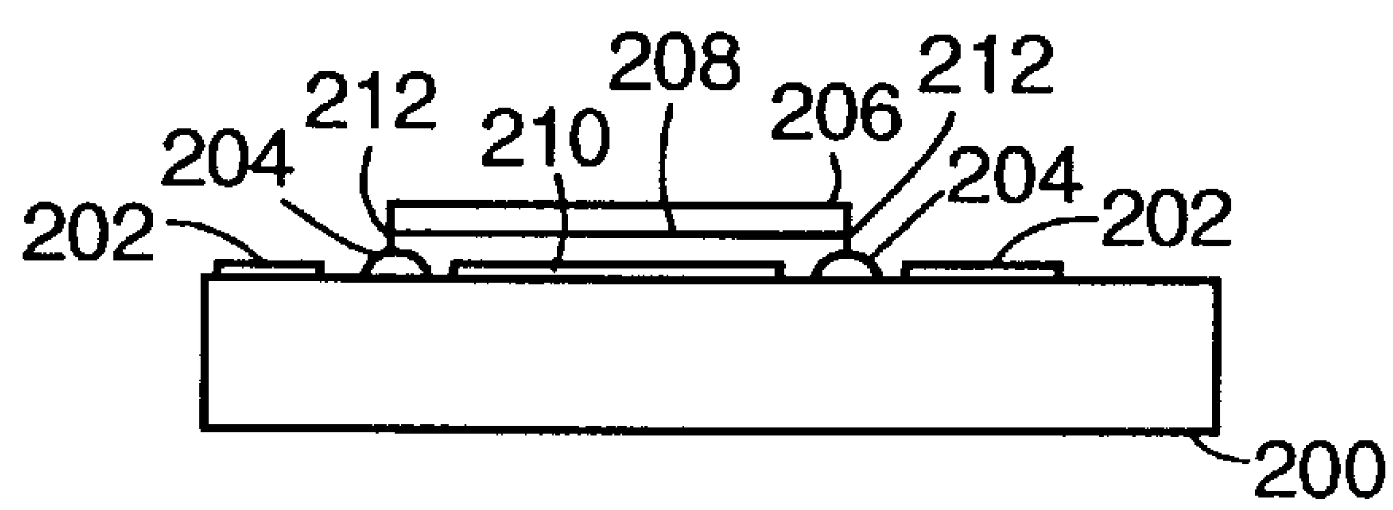

208
212
206
212
204
210
204
202
202
200

FIG. 2

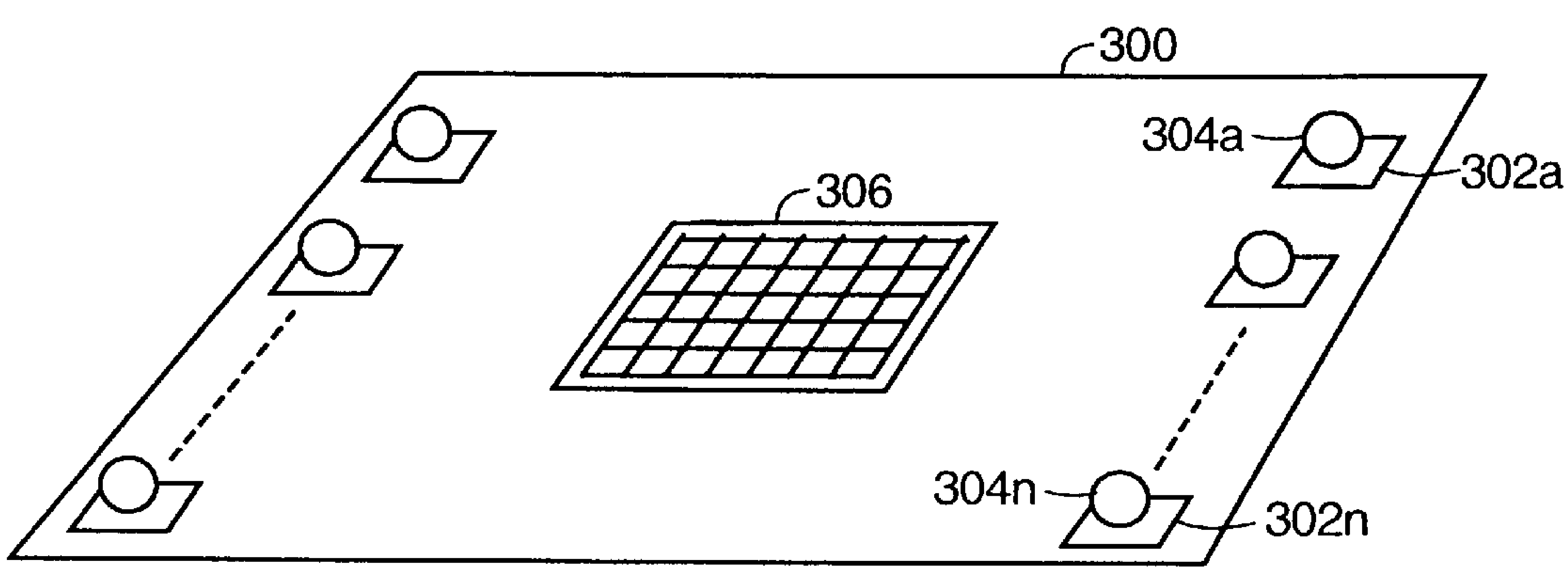

300
304a
302a
306
304n
302n

FIG. 3

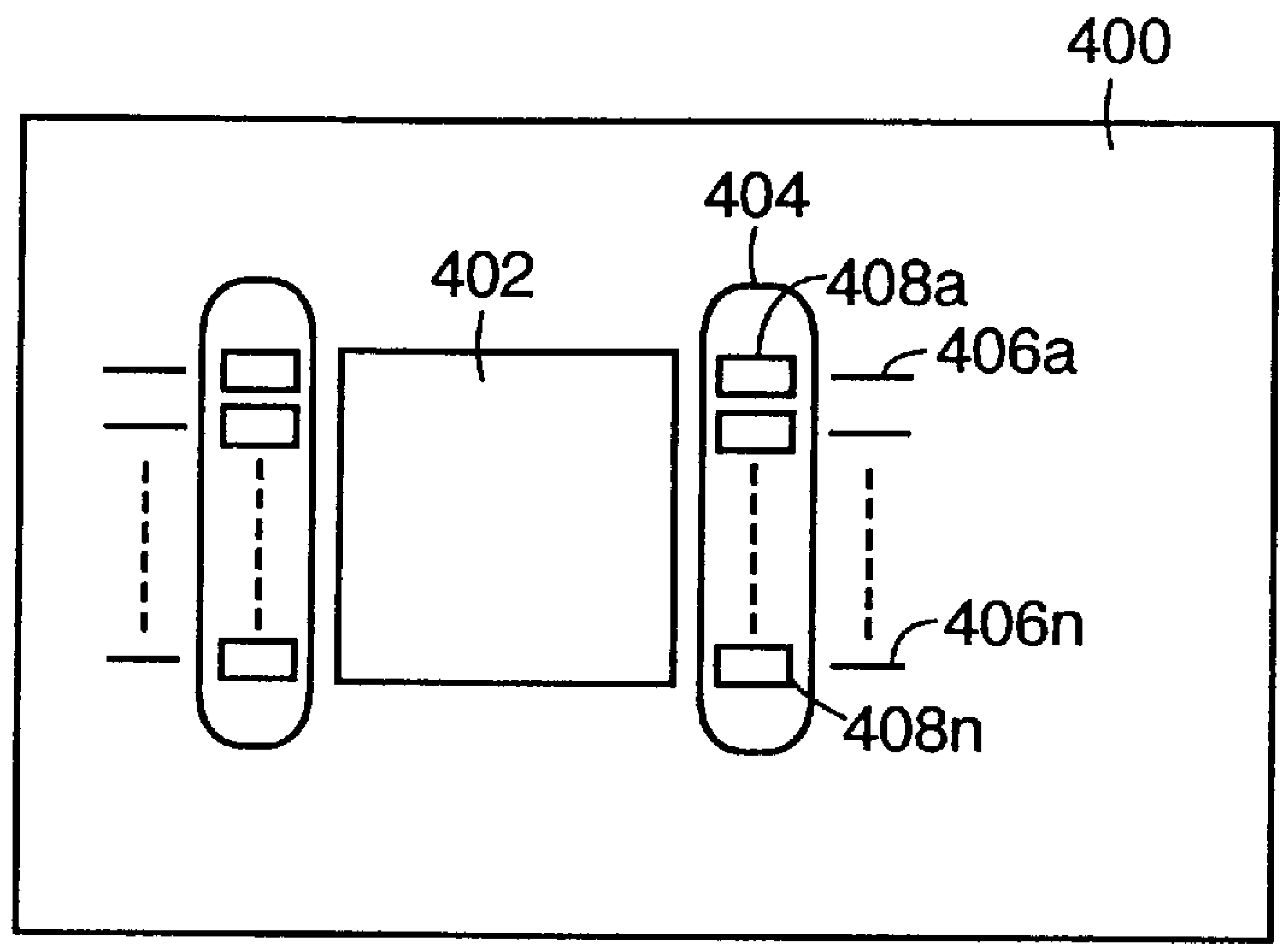

400
404
402
408a
406a
406n
408n

FIG. 4

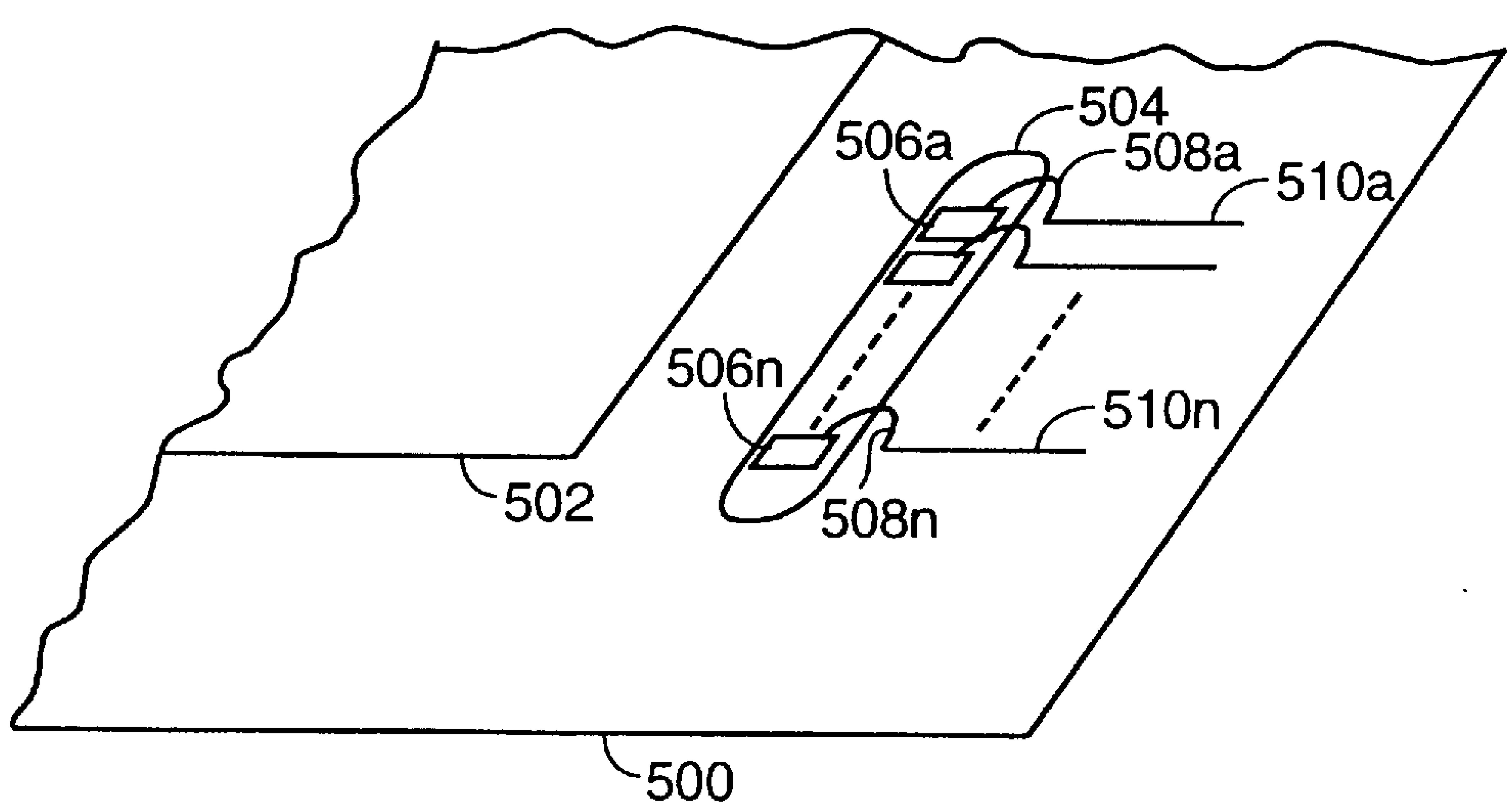

504
506a
508a
510a
506n
510n
502
508n
500

FIG. 5

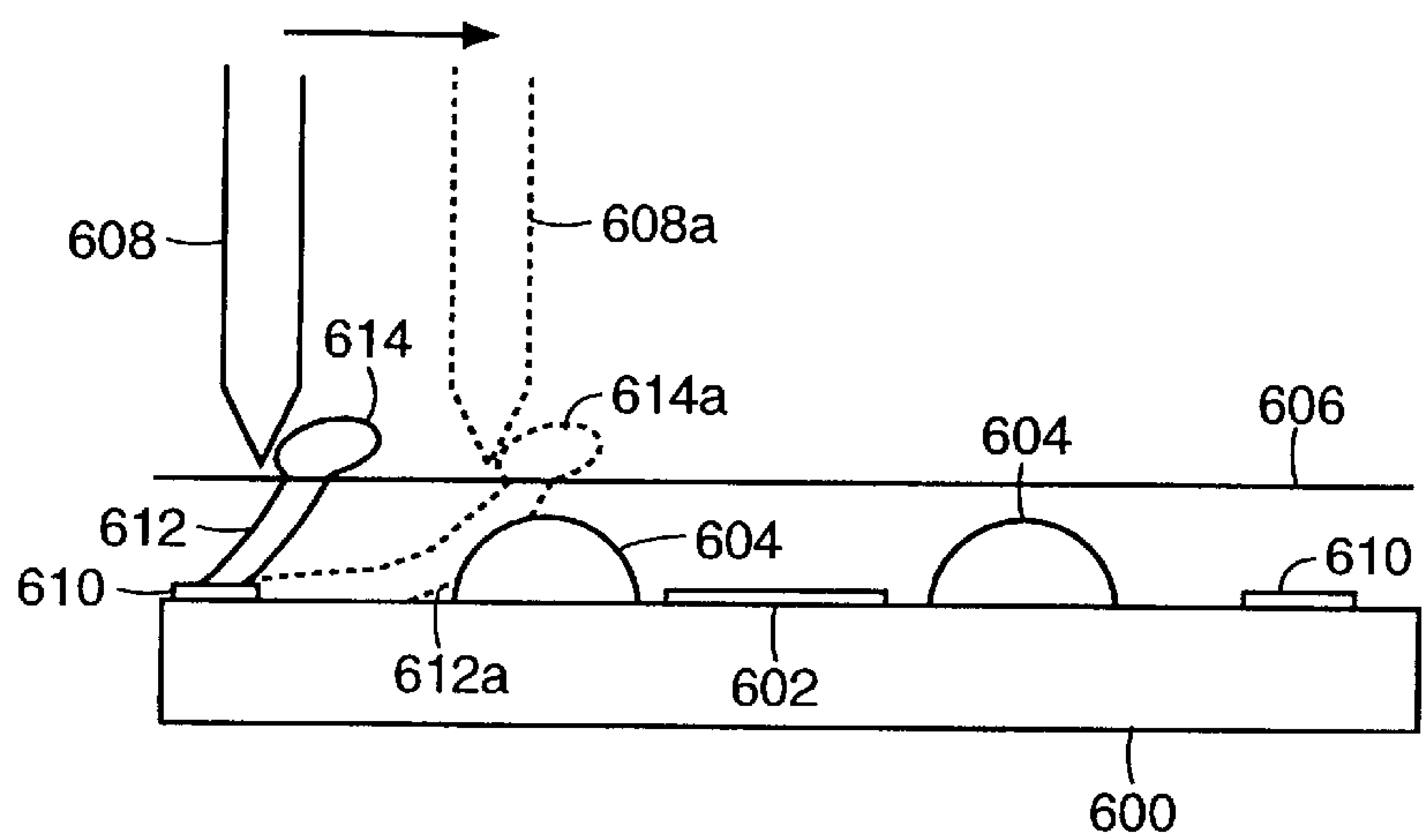

608
608a
614
614a
604
606
612
604
610
610
612a
602
600

FIG. 6

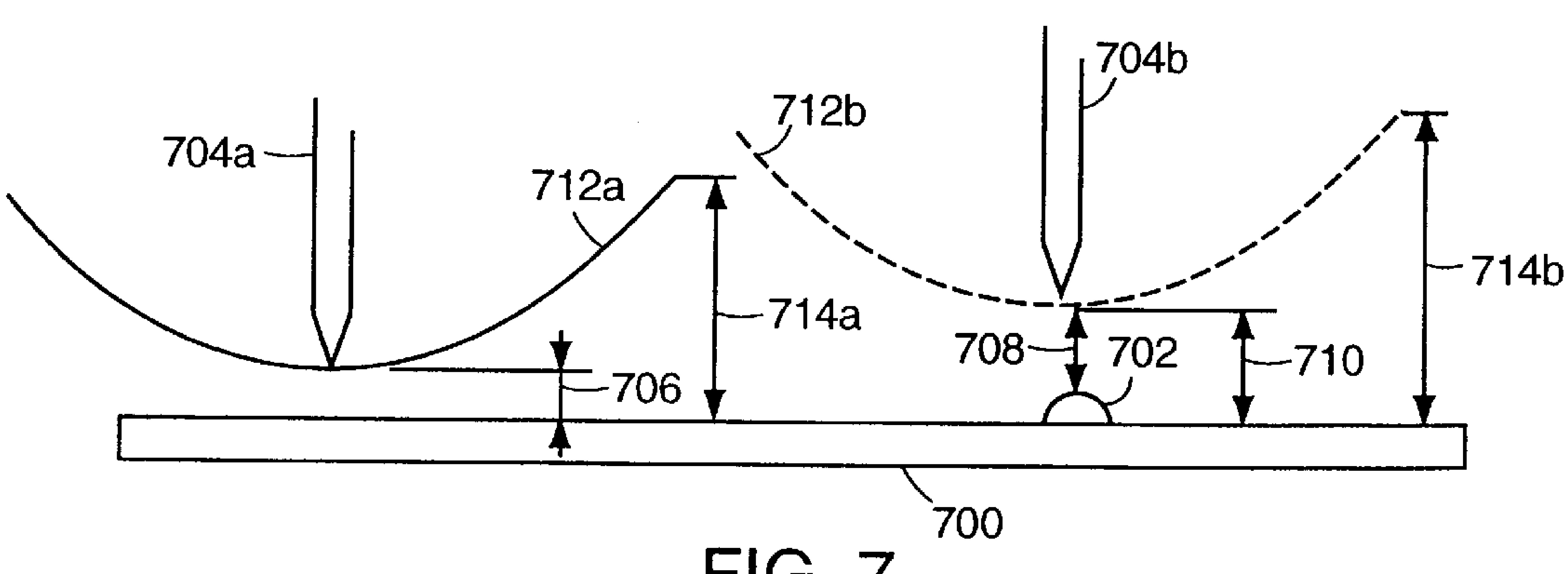

704b
712b
704a
712a
714b
714a
708
702
710
706
700

FIG. 7

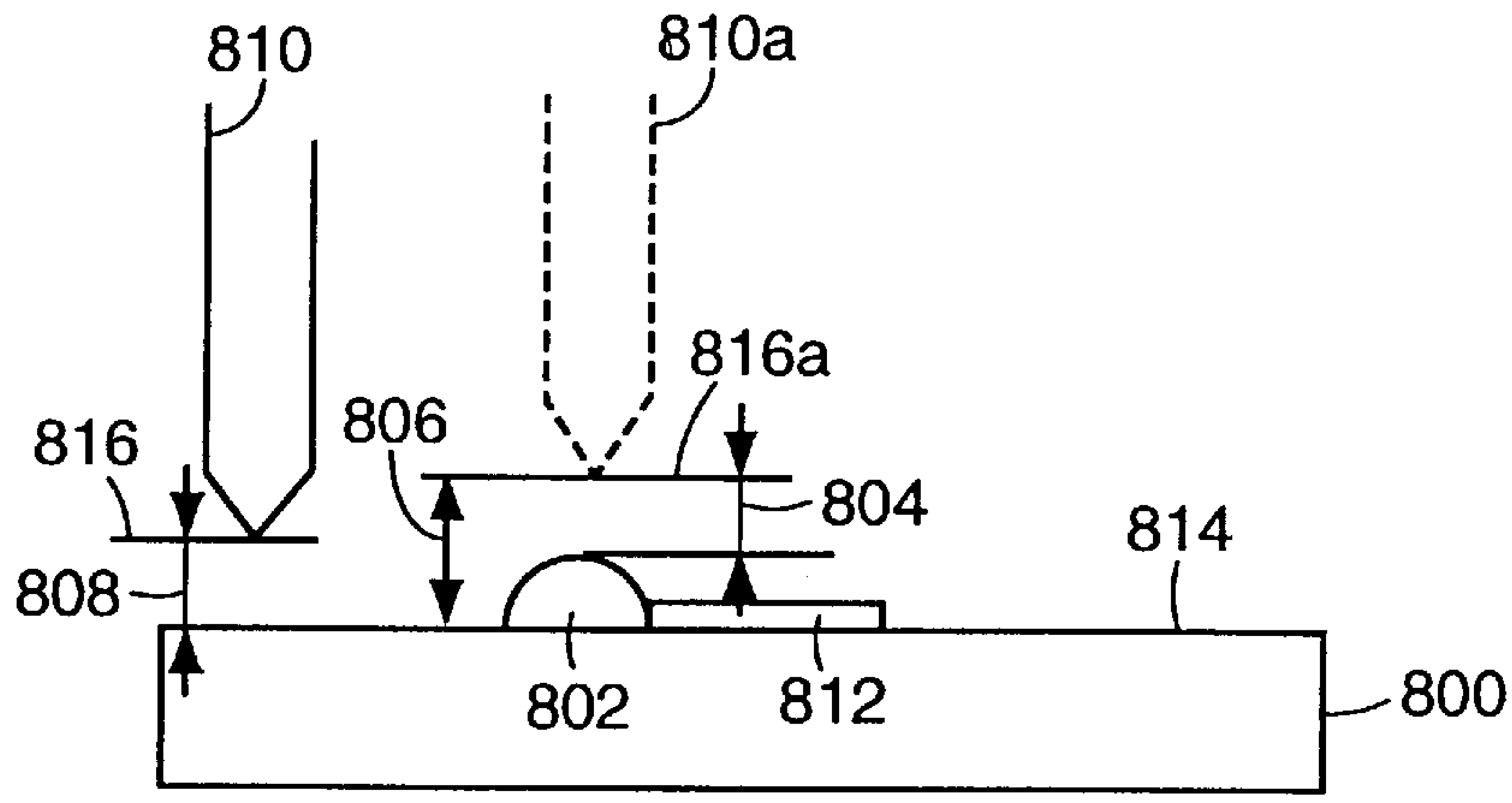

810
810a
816a
816
806
804
814
808
802
812
800

FIG. 8

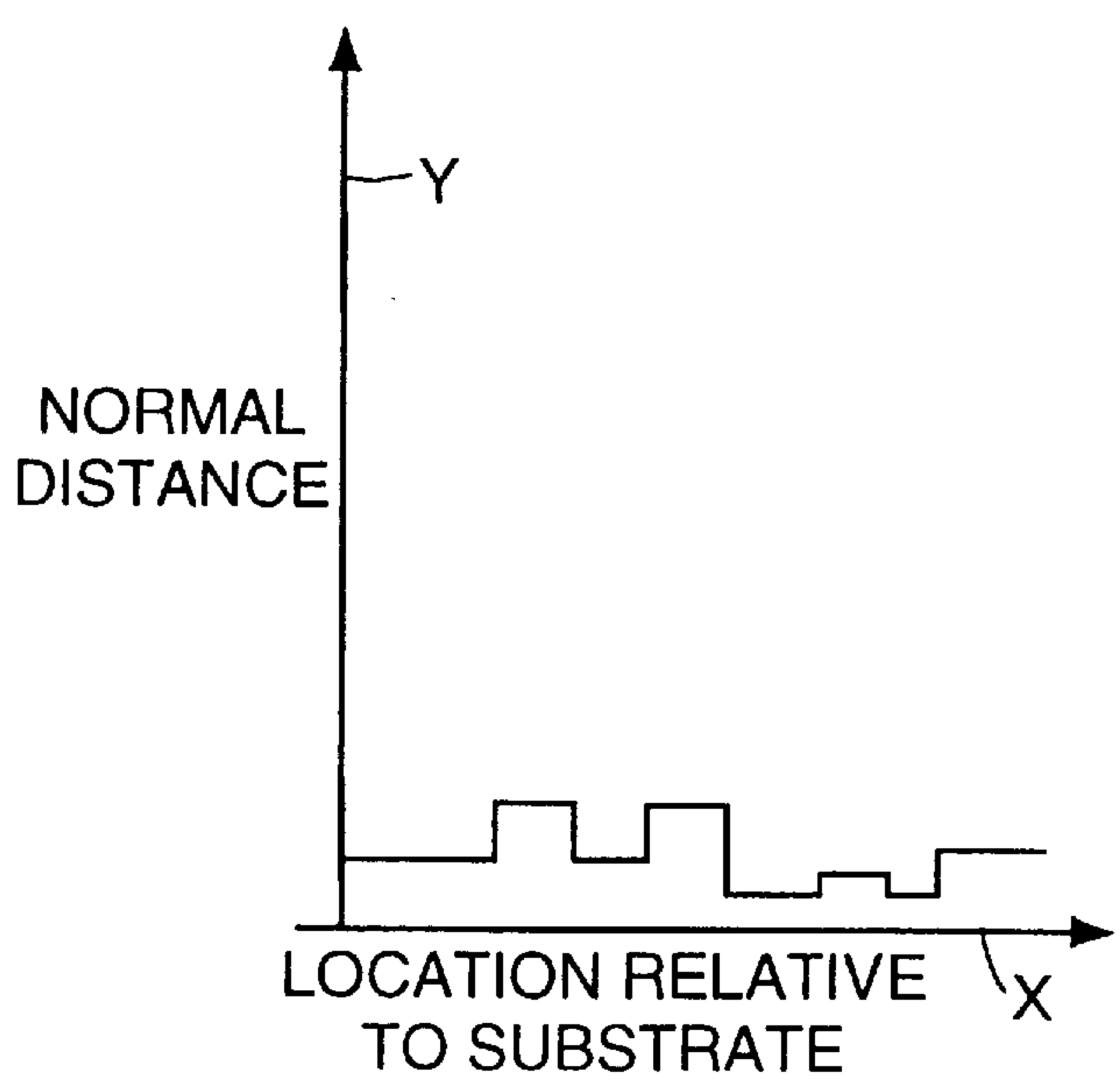

Y
NORMAL
DISTANCE
LOCATION RELATIVE
TO SUBSTRATE
X

FIG. 8A

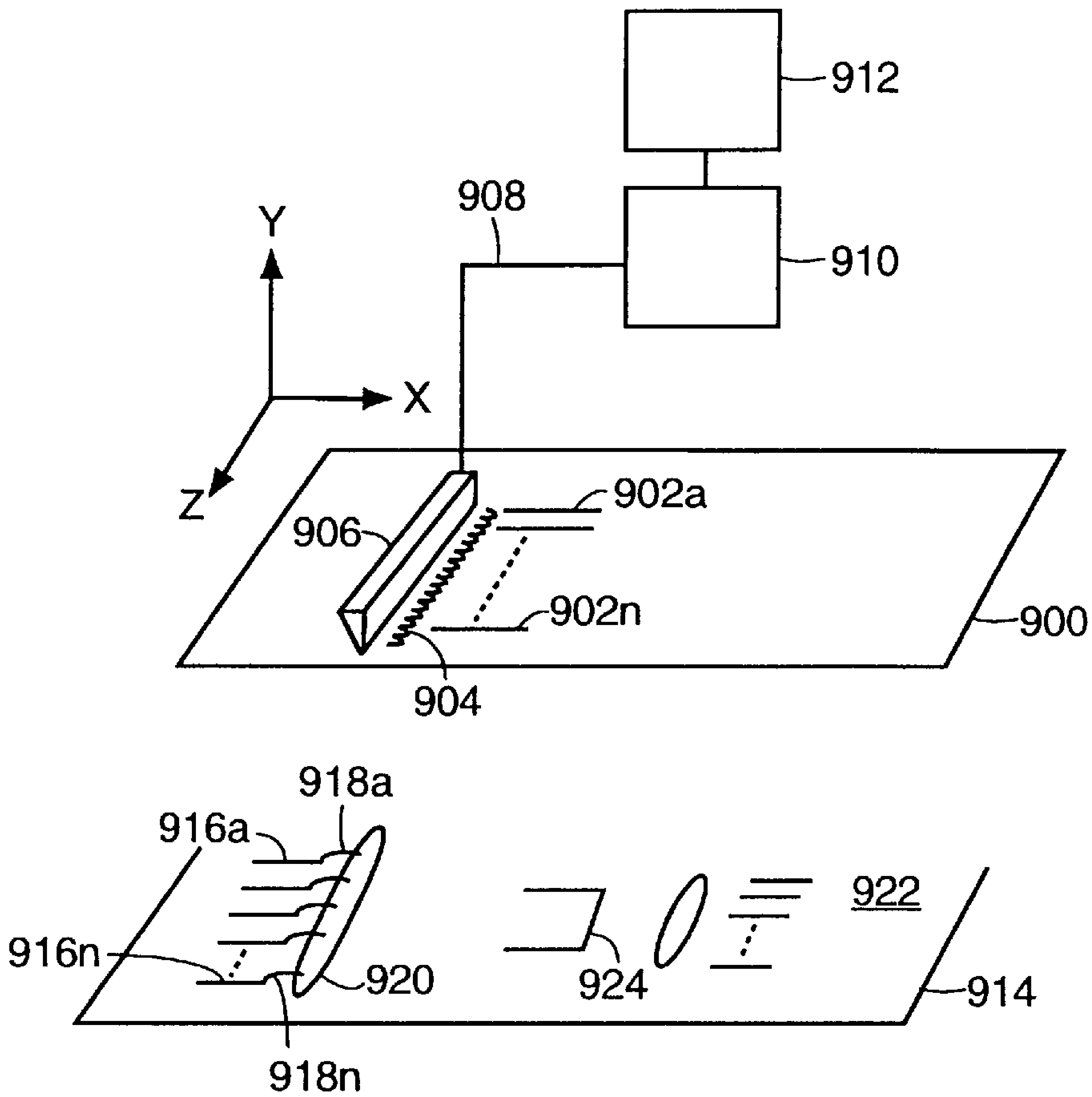

912
910
908
Y
X
Z
906
902a
902n
900
904
918a
916a
922
916n
920
924
914
918n

FIG. 9

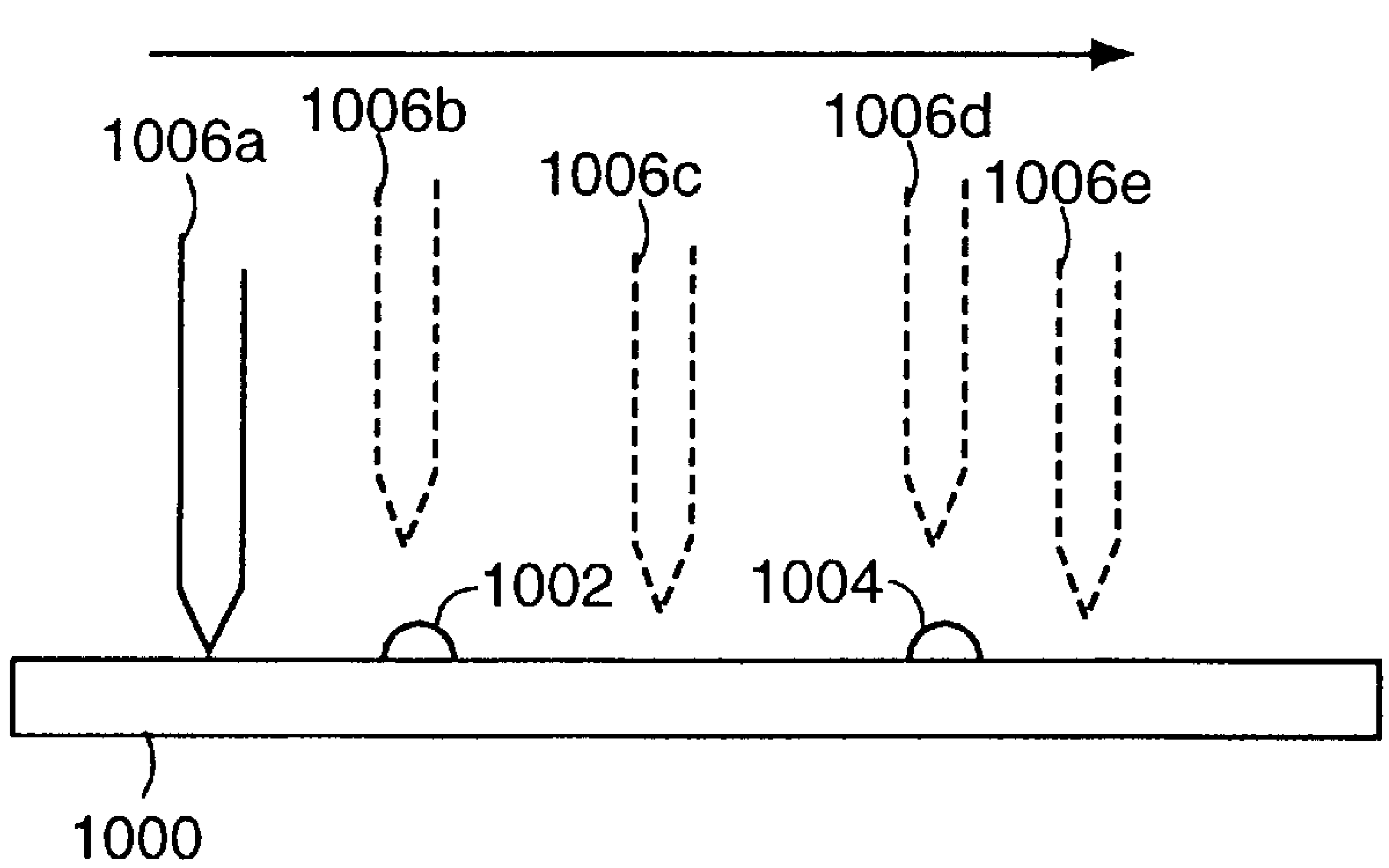

1006a
1006b
1006c
1006d
1006e
1002
1004
1000

FIG. 10

MULTIPLE LEVEL PRINTING IN A SINGLE PASS

GOVERNMENT RIGHTS

This invention was made with Government support under Contract No. DABT 63-93-C-0025 awarded by Advanced Research Projects Agency (ARPA). The Government has certain rights in this invention.

BACKGROUND OF THE INVENTION

This invention relates to the field of electronic displays, and, more particularly, field emission display ("FED") devices.

As technology for producing small, portable electronic devices progresses, so does the need for electronic displays which are small, provide good resolution, and consume small amounts of power in order to provide extended battery operation. Past displays have been constructed based upon cathode ray tube ("CRT") or liquid crystal display ("LCD") technology. However, neither of these technologies is perfectly suited to the demands of current electronic devices.

CRT's have excellent display characteristics, such as, color, brightness, contrast and resolution. However, they are also large, bulky and consume power at rates which are incompatible with extended battery operation of current portable computers.

LCD displays consume relatively little power and are small in size. However, by comparison with CRT technology, they provide poor contrast, and only limited ranges of viewing angles are possible. Further, color versions of LCDs also tend to consume power at a rate which is incompatible with extended battery operation.

As a result of the above described deficiencies of CRT and LCD technology, efforts are underway to develop new types of electronic displays for the latest electronic devices. One technology currently being developed is known as "field emission display technology."The basic construction of a field emission display, or ("FED") is shown in FIG. **1**. As seen in the figure, a field emission display comprises a face plate **100** with a transparent conductor **102** formed thereon. Phosphor dots **112** are then formed on the transparent conductor **102**. The face plate **100** of the FED is separated from a baseplate **114** by a spacer **104**. The spacers serve to prevent the baseplate from being pushed into contact with the faceplate by atmospheric pressure when the space between the baseplate and the faceplate is evacuated. A plurality of emitters **106** are formed on the baseplate. The emitters **106** are constructed by thin film processes common to the semi-conductor industry. Thousands of emitters **106** are formed on the baseplate **114** to provide a spatially uniform source of electrons.

FIG. **2** shows a basic construction of a typical field emission display device. As shown, there is a substrate **200** formed of a transparent material, for example, glass. On the substrate **200**, there is formed conductors **202** and spacers **204**. When the FED is finally assembled, conductors **202** will form the contact points necessary to connect the FED into an electronic circuit. Spacers **204** provide the required separation between die **206** and substrate **200**. Without spacers **204**, the die **206** would be forced together with substrate **200** by atmospheric pressure when the device is evacuated. Die **206** has surface **208** which has formed thereon the emitters which will emit electrons to form an image on phosphor layer **210**. Also formed on surface **208** of die **206** are a plurality of contact pads **212** which will be connected to conductors **202** to allow operation of the device.

One method for connecting the bond pads on surface **208** to the conductors **202** is a method referred to as "flip chip" bonding. This technique is described with reference to FIGS. **3** and **4**. FIG. **3** shows an example of a die **300** suitable for flip chip bonding. In this example, die **300** has contact pads **302**_a_–**302**_n_ for providing electrical connection to emitters **306**. Bonding pads **302**_a_–**302**_n_ have formed thereon conductive "bumps" **304**_a_–**304**_n_. Bumps **304**_a_–**304**_n_ provide the electrical connection necessary to the corresponding conductors on the spacers as shown in FIG. **4**.

FIG. **4** is a diagram of a substrate **400** having formed thereon a phosphor layer **402**, a spacer **404** and a plurality of conductors **406**_a_–**406**_n_. Formed on the upper surface of spacer **404** are a plurality of conductors **408**_a_–**408**_n_ for providing electrical connection to bond pads **302**_a_–**302**_n_ by conductive bumps **304**_a_–**304**_n_ (see FIG. **3**). However, it is still necessary to provide electrical communication between conductors **408**_a_–**408**_n_ formed on the spacer and conductors **406**_a_–**406**_n_ formed on the substrate **400**. One method for providing this communication is shown in FIG. **5**.

FIG. **5** is a top view of a substrate **500** having the conductors **506**_a_–**506**_n_ on the spacer **504** electrically connected to the conductors **510**_a_–**510**_n_ on the substrate **500**. As shown in FIG. **5**, substrate **500** has formed thereon phosphor layer **502**, spacer **504** and conductors **510**_a_–**510**_n_. Spacer **504** has formed, on an upper surface, conductors **506**_a_–**506**_n_. Spacer conductors **506**_a_–**506**_n_ are electrically connected to substrate conductors **510**_a_–**510**_n_ by bonding wires **508**_a_–**508**_n_. However, the connecting scheme shown in FIG. **5** is undesirable because it requires that additional manufacturing steps be taken to bond each bonding wire **508**_a_–**508**_n_ between the proper conductors on the substrate **500** and the spacer **504**.

There has therefore been a need in the industry for a method and apparatus to connect substrate conductors to spacer conductors without the use of bond wires.

SUMMARY OF THE INVENTION

According to one embodiment of the invention, a process is provided for forming a conductive line between a conductor and a spacer formed on a substrate of a field emission display, the process comprising disposing a screen between the substrate and a distributing member, the screen having an opening which permits the passage of conductive material, and moving the distributing member along the screen to pass the conductive material through the opening and form a conductive line connecting the conductor and the spacer.

According to another embodiment of the invention, an apparatus is provided for forming a conductive line between a conductor and a spacer with the aid of a screen, the conductor and the spacer being formed on a substrate of a field emission display, the screen being disposed between the substrate and a distributing member and having an opening which permits the passage of conductive material. According to an aspect of the invention, the apparatus comprises a control circuit which moves the distributing member along the screen to pass the conductive material through the opening and form a conductive line connecting the conductor and the spacer.

BRIEF DESCRIPTION OF THE DRAWINGS

For a more complete understanding of the invention and for further advantages thereof, reference is made to the following Detailed Description taken in conjunction with the accompanying drawings, in which:

FIG. **1** is a plan view showing the operation of a typical FED device.

FIG. **2** is a plan view showing the construction of a FED device.

FIG. **3** is a top view of the substrate of a FED device having bumps suitable for flip chip bonding.

FIG. **4** is a top view of a substrate of a FED device useful with the present invention.

FIG. **5** is a plan view of a substrate using bonding wires.

FIG. **6** is a plan view of a FED substrate showing the operation of the distributing member according to another embodiment of the invention.

FIG. **7** is a plan view according to the present invention.

FIG. **8** is a plan view of a FED showing the operation of the distributing member according to one embodiment of the invention.

FIG. **8**A is a graph of the distance between the distributing member and the substrate according as the distributing member moves along the substrate to an aspect of the invention.

FIG. **9** is a block diagram of an apparatus according to the present invention.

FIG. **10** is a plan view showing the vertical movement of the distributing member as it moves along the substrate.

It is to be noted, however, that the appended drawings illustrate only typical embodiments of this invention and are therefore not to be considered limiting of its scope, for the invention may admit to other equally effective embodiments.

DETAILED DESCRIPTION OF EMBODIMENTS OF THE INVENTION

Referring now to FIG. **6**, a process according to an embodiment of the invention is provided for forming a conductive line **612** between a conductor **610** and a spacer **604** formed on a substrate **600** of a field emission display. In one aspect, the process comprises disposing a screen **606** between the substrate **600** and a distributing member **608**, the screen **606** having an opening which permits the passage of a conductive material **614**, and moving the distributing member **608** along the screen **606** to pass the conductive material **614**, through the opening and form a conductive line **612** connecting the conductor **610** and the spacer **604**. In the FIG. **6** embodiment, the distributing member **608** is moved along the screen **606** to the position shown by dotted line **608***a*. As it moves, it pushes conductive material **614** along with it so that a conductive line **612** is formed as shown by dotted line **612***a*. An example of a conductive material **614** known to be useful is a gold palladium paste such as TFAUPD 7395 manufactured by IMRC of Tuson, Az. Other examples of a useful conductive material would be EMCA, DuPont, or Ferro Conductor series. Other examples of conductive materials will occur to those skilled in the art.

It is to be noted that in the FIG. **6** embodiment, the conductive line **612** connects the conductor **610** to the upper surface of the spacer **604**. Therefore, the spacer end of the conductive line **612** also functions as a spacer conductor to provide electrical communication between the bonding pads of the die (not shown) and the conductor **610**. However, it will be understood by those of skill in the art that a spacer conductor could be formed in a separate operation and then connected to the conductor **610** with conductive line **612**.

It will also be understood by those of skill in the art that it is possible to construct the distributing member according to various shapes as long as it functions to distribute the conductive material. For example, in one aspect, the distributing member is a squeegee which is drawn along the surface of the screen.

Examples of a useful material for manufacturing the screen are polyester or stainless steel mesh manufactured by Rigsby Screen of Torrance, Ca. Other examples of useful screen material will occur to those of skill in the art who recognize that screen materials having the properties of flexibility, material resistance and strength may be employed.

FIG. **8** shows another aspect of the invention wherein the snap off distance **808** between the screen **816** and the substrate **800** is varied responsive to the spacer **802**. As shown in FIG. **8** embodiment, as the distributing member **810** moves to the position shown by dotted line **810***a*, the snap off distance **808** between screen **816** and substrate **800** increases to the distance **806** between the screen **816***a* and substrate **800**. In this way, the height of the spacer **802** above the surface of the substrate **800** is taken into account as the conductive lines (not shown) are formed. This provides several advantages. For example, it prevents damage to the phosphor layer **812** formed on substrate **800** due to contact between the screen and the phosphors. Also, it eliminates separate processing using expensive equipment, such as wire bonders. Further, reliability is increased since the reliability of a thick film conductor is better than a wire bond. Also, it permits for a more uniform pressure to be placed on the screen **816**. Moreover, resistivity is lowered and current load is increased.

According to still a further aspect of the invention, the snap off distance **808** between the screen **816** and the substrate **800** is varied responsive to predetermined parameters. For example, referring now to FIG. **8**A, there is shown a graph in which the distance between the screen and the substrate is plotted along the Y axis relative to the location of the distributing member and the substrate on the X axis. As the distributing member is moved along the substrate in the X direction, its distance, or height, above the substrate is varied according to predetermined parameters. In one aspect, these parameters are stored in the memory of a computer which controls the movement of the distributing member in both the X and Y directions. These predetermined parameters are selected to maximize performance of different embodiments of the invention. Referring again to FIG. **8**, another embodiment is provided in which moving the distributing member **810** comprises maintaining a substantially constant snap off distance **808** between the screen **816** and an upper surface of the substrate **814**. As used herein, the upper surface of the substrate includes the upper surface of objects formed on the substrate, for example, the spacer **802**. For example, in one version of the invention, when the distributing member **810** moves to the position shown by dotted line **810***a*, the distance **808** from the screen **816** to the substrate **800** is the same as the distance **804** from the screen **816***a* to spacer **802**, even though the distance between the screen **816***a* and substrate **800** actually increases to distance **806**. According to another embodiment of the invention, the constant snap off distance is maintained at about 0.01 to about 0.08 inches from the substrate **800**. In another aspect, the snap off distance is maintained at about 0.025 to about 0.075 inches. According to other embodiments of the invention, the distance **804** may be different than the distance **808**.

Referring now to FIG. **7**, it will be noted that when pressure is applied to the screen **712***a* by distributing member **704***a*, the screen **712***a* deflects as shown. Therefore, the nearest distance between the screen **712***a* and the substrate surface **700** is **706** as shown, even though the snap off distance **714***a* is somewhat greater. In order to maintain a constant distance between the screen **712***b* and the substrate surface when the distributing member **704***a* is at position **704***b* it is necessary to increase the snap off distance **714***a* to snap off distance **714***b*.

Therefore, in one embodiment, the invention allows for operation with two snap off distances in which the second snap off distance **714***b* equals the first snap off distance **714***a* plus the height of the spacer **702** above the substrate **700**. In one aspect, the snap off distance is varied by moving the screen **712***a* in relation to the substrate. Alternatively, the snap off distance is varied by moving the substrate away from the screen **712***a*. Those of skill in the art will recognize that more than two snap off distances are used according to other embodiments of the invention, and that the additional snap off distances are not necessarily selected solely to maintain a constant distance between the substrate surface and the screen.

For example, with reference to FIG. **8**, in other embodiments of the invention, the snap off distance **808** is selected to achieve desired results. In one aspect of the invention, moving the distributing member **810** comprises varying the snap off distance **808** between the screen **816** and an upper surface **814** of the substrate **800** such that no damage occurs to the phosphor layer **812**. In another example, moving the distributing member **810** comprises varying the snap off distance **808** between the screen **816** and an upper surface of the substrate **814** such that a substantially constant pressure is maintained on the upper surface **814** by the distributing member **810**. In one aspect, the pressure is maintained at about 1 to about 60 psi. In another embodiment, the pressure is maintained between about 10 and about 30 psi. In another aspect, the pressure is maintained between about 15 and about 35 psi. In another aspect, moving the distributing member **810** comprises maintaining a substantially constant pressure on the screen **816** with the distributing member **810**.

According to still a further embodiment, moving the distributing member **810** comprises moving the distributing member **810** along the substrate **800** at a velocity of about 1.0 to about 12.0 inches per second. In still a further embodiment, the velocity is between about 2.0 and about 8.0 inches per second.

Of course, it will be recognized that the screen must be held in place while the operation to form the conductive line is performed. In one example of an embodiment, placing a screen comprises bolting a screen frame to a machine with an X, Y and θ adjustment for aligning the conductor to the substrate.

Referring now to FIG. **9**, in one aspect of the invention, there is provided an apparatus for forming conductive lines **918***a*–**918***n* between conductors **916***a*–**916***n* and a spacer **920** with the aid of a screen **900**, the conductors **916***a*–**916***n* and the spacer **920** being formed on a substrate **914** of a field emission display, the screen **900** being disposed between the substrate **914** and a distributing member **906** and having openings **902***a*–**902***n* which permit the passage of a conductive material **904**. According to one embodiment of the invention, the apparatus comprises a control circuit **912** which moves the distributing member **906** along screen **900** to pass the conductive material **904** through the openings **902***a*–**902***n* and form conductive lines **918***a*–**918***n* connecting the conductors **916***a*–**916***n* and the spacer **920**. In one embodiment, control circuit **912** operates a servo system **910** which controls the movement of distributing member **906**. An example of an acceptable control circuit **912** would be an MPC-29 manufactured by DeHaart Corp. of MA. Other examples of control systems useful to control the distributing member will occur to those skilled in the art. In a further embodiment, the control circuit **912** varies the snap off distance between the screen **900** and the substrate **914** responsive to the spacer **920**. In a still further aspect, the control circuit **912** varies the snap off distance between the screen **900** and the substrate **914** responsive to predetermined parameters stored in the control circuit memory. In an even further embodiment, the control circuit **912** moves the distributing member **906** such that a substantially constant distance between the screen **900** and an upper surface **922** of the substrate **914** is maintained. Alternatively, the control circuit **912** varies the distance between the screen **900** and an upper surface **922** of the substrate **914** such that no damage occurs to the phosphor layer **924**. In yet a further embodiment, the control circuit **912** varies the distance between the screen **900** and an upper surface **922** of the substrate **914** such that a substantially constant pressure is maintained on the upper surface **922** by the distributing member **906**.

FIG. **10** shows an embodiment of the invention in which a substrate **1000** is provided with spacers **1002** and **1004**. A distributing members **1006** moves along the surface of a substrate **1000** from position **1006**A to **1006**B, **1006**C, **1006**D and **1006**E. It is seen from the drawing that the vertical distance from the distributing member **1006** to the substrate **1000** changes as it passes over spacers **1002** and **1004**.

What is claimed is:

1. A process for forming a conductive line between a conductor and a spacer formed on a substrate of a field emission display, the process comprising:

disposing a screen between the substrate and a distributing member, the screen having an opening which permits passage of conductive pastes;

moving the distributing member along the screen to pass conductive paste through the opening and form a conductive line connecting the conductor and the spacer.

2. A process as in claim **1** further comprising a step of moving the screen so as to maintain a first distance between the screen and the substrate when the distributing member is disposed over the conductor and to maintain a second distance between the screen and the substrate when the distributing member is disposed over the spacer.

3. A process as in claim **1** wherein moving the distributing member along the screen comprises a step of moving the screen to maintain a substantially constant distance between an upper surface of the substrate and a point on the screen where the distributing member contacts the screen.

4. A process as in claim **3** wherein the constant distance is maintained at about 0.025 to about 0.075 inches.

5. A process as in claim **1** wherein moving the distributing member along the screen comprises a step of moving the screen such that the screen remains spaced apart from a phosphor layer on the substrate.

6. A process as in claim **1** wherein moving the distributing member comprises maintaining a substantially constant pressure on an upper surface of the substrate by the distributing member.

7. A process as in claim **6** wherein the pressure is maintained at about 15 to about 35 lbs.

8. A process as in claim **1** wherein moving the distributing member comprises maintaining a substantially constant pressure on the screen with the distributing member.

9. A process as in claim **1** wherein moving the distributing member comprises moving the distributing member substantially parallel to the upper surface of the substrate at a velocity of about 2 to about 10 inches per minute.

10. A process as in claim **1** wherein the conductive paste comprises gold and palladium.

11. A process for depositing a conductive paste onto an structure that includes

a surface, and

a spacer having a top portion and a bottom portion, the bottom portion being disposed on a first location of the surface and the top portion being spaced apart from the surface,

the process comprising:

disposing a screen over the surface, the screen defining an aperture;

moving the screen relative to the surface;

pushing the conductive paste through the aperture towards the surface and thereby depositing conductive paste that extends from a portion of the surface to the top portion of the spacer.

12. A process according to claim **11**, wherein the pushing step comprises moving a distributing member from a first position to a second position to push the conductive paste through the aperture, the first position being proximal to a second location on the surface and the second position being proximal to the top portion of the spacer.

13. A process according to claim **12**, wherein the pushing step further comprises maintaining contact between the distributing member and the screen while the distributing member moves from the first position to the second position.

14. A process according to claim **12**, wherein the pushing step comprises positioning the distributing member so that at least a portion of the distributing member contacts and applies a pressure to at least a portion of the screen.

15. A process according to claim **14**, wherein the pushing step comprises maintaining the pressure at a substantially constant value as the distributing member moves from the first position to the second position.

16. A process according to claim **11**, wherein the pushing step comprises moving a distributing member relative to the screen.

17. A process according to claim **11**, wherein the paste comprises gold.

18. A process according to claim **11**, wherein the paste comprises palladium.

19. A process according to claim **11**, wherein the step of moving the screen comprises varying a distance between the screen and at least a portion of the surface.

20. A process according to claim **19**, wherein the steps of moving the screen and pushing the conductive material comprise simultaneously moving the screen and a distributing member.

21. A process for depositing a conductive paste onto a surface, comprising:

disposing a screen over the surface, the screen defining an aperture;

simultaneously moving the screen relative to the surface and passing the conductive paste through the aperture onto the surface.

22. A process according to claim **20**, wherein passing the conductive paste comprises moving a distributing member relative to the screen.

23. A process according to claim **20**, wherein moving the screen comprises varying a distance between the screen and at least a portion of the surface.

* * * * *